Influence of electro-discharge machining on tribological behaviour of hardmetals

Koenraad Bonny, Patrick De Baets

Abstract – **Electro-discharge machining (EDM) [1,2] is a manufacturing process that allows to create shapes in materials irrespective of their mechanical properties, provided they are electrically conductive. *Hardmetals* are wear resistant ceramic materials that satisfy this condition. In an attempt to improve the wear resistance of EDM-treated hardmetals, relationships between EDM-parameters and wear behaviour of several hardmetal grades are being investigated.**

Keywords – **hardmetal, wear, friction, reciprocate sliding, electro-discharge machining (EDM)**

I. Introduction

At present, there is an enormous industrial need for materials with major engineering applications in situations where friction and wear are important, as for instance in machining and metal forming, bearings and gears. New materials or improved existing materials are called for, in order to extend the lifetime of existing devices and components and thus save resources in a sustainable economy. These materials have to combine high hardness, stiffness and wear resistance with chemical inertness. *Hardmetals* are ceramic materials that exhibit all these properties, and moreover, their electrical conductivity allows them to be shaped and manufactured by EDM. This process is thermal in nature, with material removal occurring via the discharge of energy between a tool and workpiece electrode, which are separated by a small gap, filled with a dielectric fluid. A DC pulse generator is used to initiate discrete sparks, which have a duration in the region of 0.2-100 µs, followed by a similar period during which deionisation of the dielectric occurs and the gap is flushed of debris [2]. The goal of this research is to investigate the influence of the EDM-parameters on tribological behaviour.

II. Experimental

A. Test Materials

Several hardmetal grades are used for the investigation. They consist of tungsten carbide and cobalt or nickel; their hardness (Vickers) varies from 1200 kg/mm^2 up to 1800 kg/mm^2. The surfaces of the tested samples are either ground, polished or EDM-treated under different sparking regimes.

K. Bonny and P. De Baets are with the Department of Mechanical Construction and Production, Ghent University (UGent), Gent, Belgium.

E-mail: koenraad.bonny@UGent.be , patrick.debaets@UGent.be.

B. Test Rig

Hardmetal pins are slid in counterformal contact against hardmetal plates using a high frequency friction tribometer, in accordance with ASTM G133 (Fig. 1). A reciprocating sliding friction is provided by a variable-speed motor through an excentrical power transmission for the adjustment of the stroke, under a given normal load. The horizontal force, which is measured by a piezo-electric transducer, characterizes the friction coefficient μ. The drop in height of the moving specimen is recorded in order to indicate the wear.

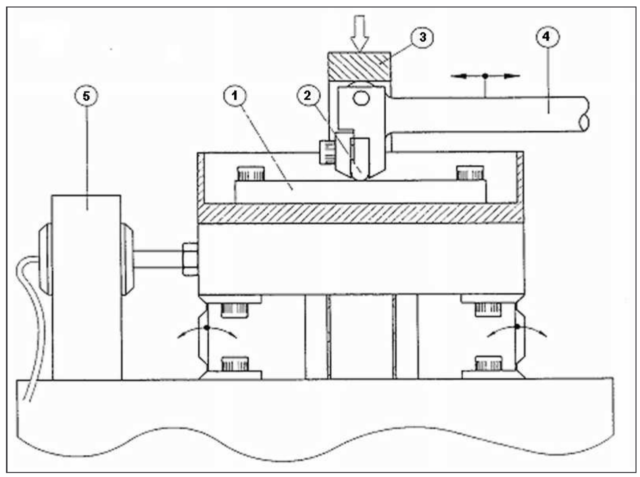

Fig. 1. PLINT TE77 High Frequency Friction Machine: (1) fixed hardmetal plate; (2) sliding hardmetal pin; (3) bridge for normal loading; (4) reciprocative moving arm; (5) piezo-electrical transducer

C. Test Conditions

The test rig is surrounded by a box, in which temperature and humidity can be regulated by means of an external climate chamber. The friction experiments are performed in an atmosphere at 23 °C and a relative humidity of 60 %. Normal loads, ranging from 15 N up to 50 N, and sliding frequencies, varying from 10 Hz up to 30 Hz are applied to the hardmetals. The distance of the reciprocating sliding motion is 15 mm.

The selection of realistic wear test conditions is based on the Hertz laws [4], which allow a mean contact pressure calculation between two sliding surfaces for a given normal load.

III. Test Results

A. Friction and wear

From the measured horizontal friction force, a statical and a dynamical friction force can be calculated:

$$F_{stat} = \frac{F_{max} - F_{min}}{2} \qquad F_{dyn} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}[F_i - F_m]^T[F_i - F_m]}$$

The statical and dynamical friction coefficient μ is defined as the ratio of the respective friction forces and the applied normal load.

The recorded wear is measured as the maximum depth of the groove in the hardmetal plate.

The curves of friction coefficients and wear after a wear test on a polished hardmetal plate are illustrated (Fig. 2).

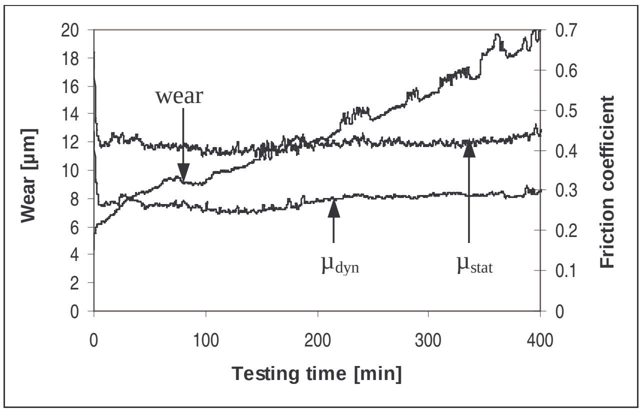

Fig. 2. Statical and dynamical friction force curve and wear curve measured during a friction experiment on a polished hardmetal plate

The measured wear is noticed to increase with increasing normal loads and with decreasing hardness of the hardmetal. It is also worth noting that during the initial tests the recorded friction force and displacement curves were relative unstable. A detailed investigation of the test rig was carried out and the necessary adjustments were made in order to optimalize further wear experiments.

B. Post-mortem analysis

Wear patterns of hardmetal plates and pins are subjected to a Scanning Electron Microscope (SEM) research and preliminary surface scanning measurements.

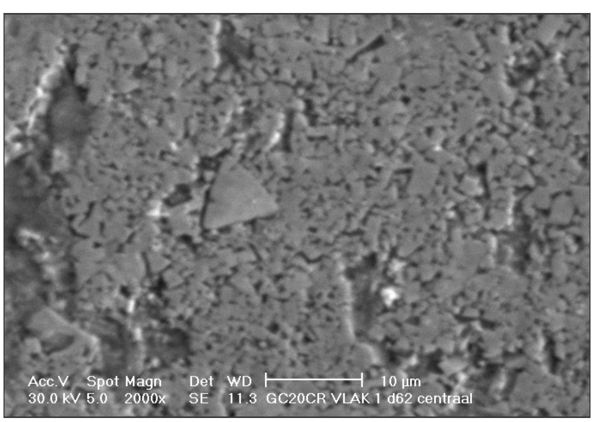

Fig. 3. SEM-photograph showing the wear track of a ground hardmetal plate after a friction experiment

Scanning electron micrographs show clearly how the hardmetals are affected after wear testing (Fig. 3). Amongst the observed wear phenomena are: polishing of the surface of the wear track, formation of wear debris especially in the outer extensions of the wear track but occasionally also present along the complete track, pull-out of individual wolfram carbide grains as well as larger chunks, and the formation of an adhering layer in the wear track [5].

A topographical surface scanning of the wear patterns of the hardmetal plates and pins allows an accurate quantification of the generated wear. A surface scan in cross direction on a polished hardmetal plate after four wear experiments with normal loads of 15 up to 50 N is illustrated in *figure 4*, which shows clearly that the wear degree increases with increasing normal loads.

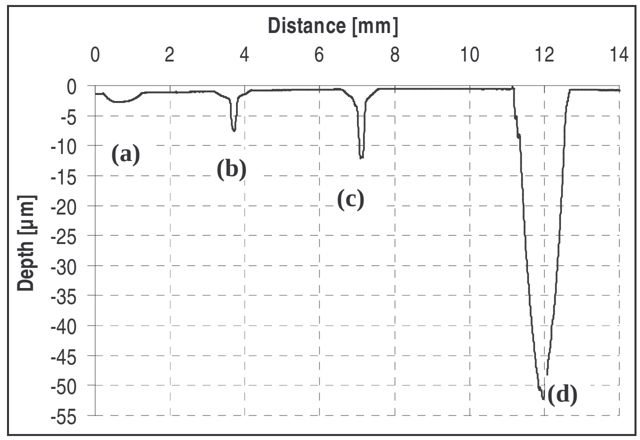

Fig. 4. Cross-directional surface scan on a polished hardmetal plate exhibiting four wear tracks after friction experiments at 15 Hz and normal loads of (a) 15 N, (b) 25 N, (c) 35 N and (d) 50 N.

IV. Conclusions and Further Research

The testing equipment is found reliable and efficient for measuring wear-resistance of hardmetals.

Wear testing of hardmetal-hardmetal combinations will be continued to investigate the influence of the EDM-regime on the friction and wear behaviour. In-depth SEM-analysis of the wear tracks will be performed, in order to clarify the influence of the recast layer generated by EDM on wear behaviour of the tribocouples. Wear patterns of both hardmetal plates and pins will be quantified by means of surface topography, in order to determine wear ratios of plate and pin and to develop wear models.

References

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